Coronagraphy with AFTA-WFIRST

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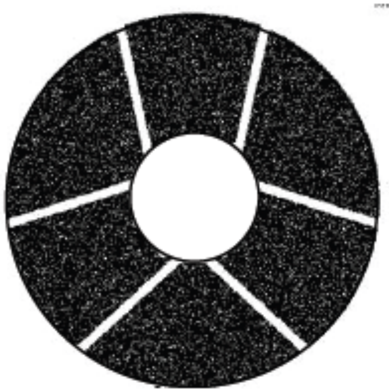
AFTA Telescope

- 2.4 m
- Inclined geosynchronous orbit
- 5 year mission
- Wide-field near-IR imager
- Coronagraphic imager&IFS
- Pupil:



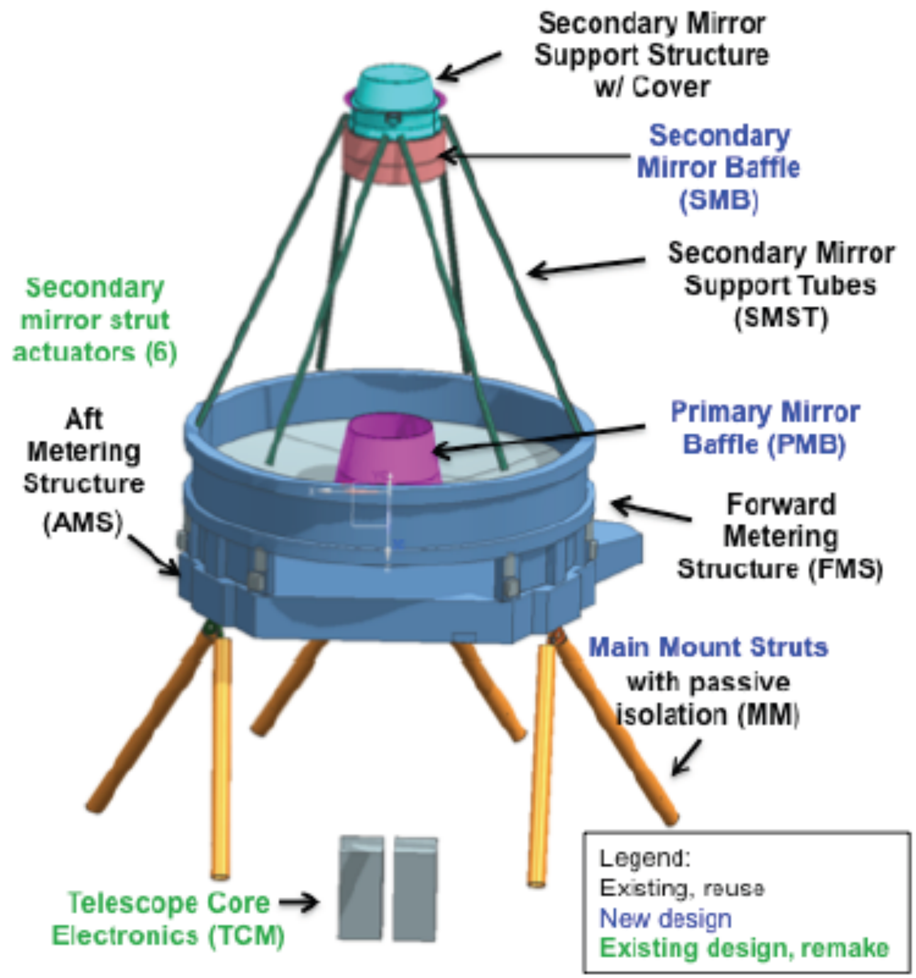


Figure 3-4: The telescope components without the outer barrel assembly.

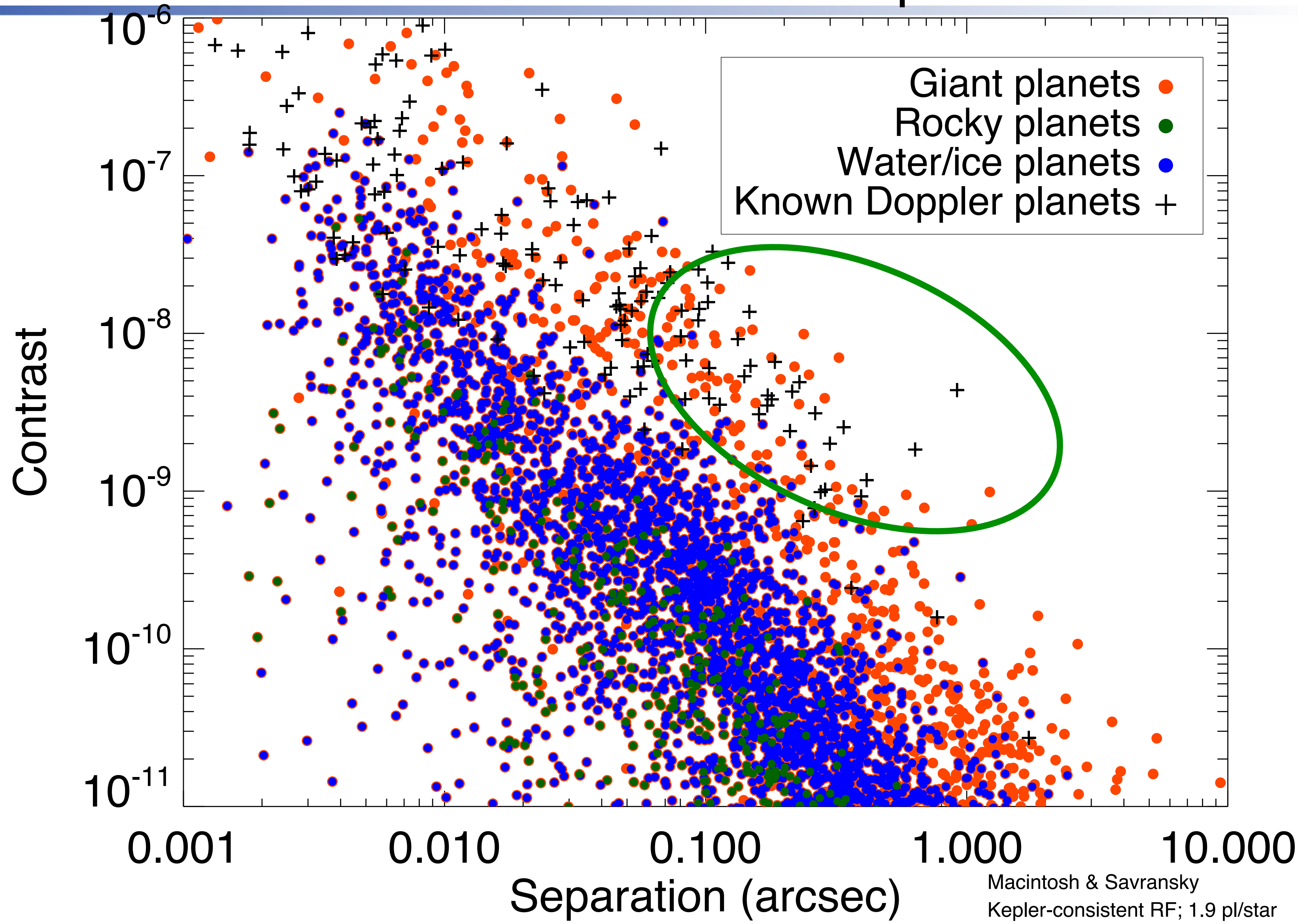
AFTA Coronagraph Goals

1) Measure and understand the composition and nature of a diverse sample of extrasolar planets orbiting nearby stars
2) Illuminate the process through which planetary systems form
3) Determine which stars have dusty remnant or debris disks, measure their disk properties, and observe how their disks and planets interact
4) Determine which systems (statistically or individually) in the solar neighborhood are suitable targets for future terrestrial-planet characterization
5) Demonstrate and validate coronagraph technology useable for a future habitable-planet-detecting mission

AFTA exoplanet science objectives

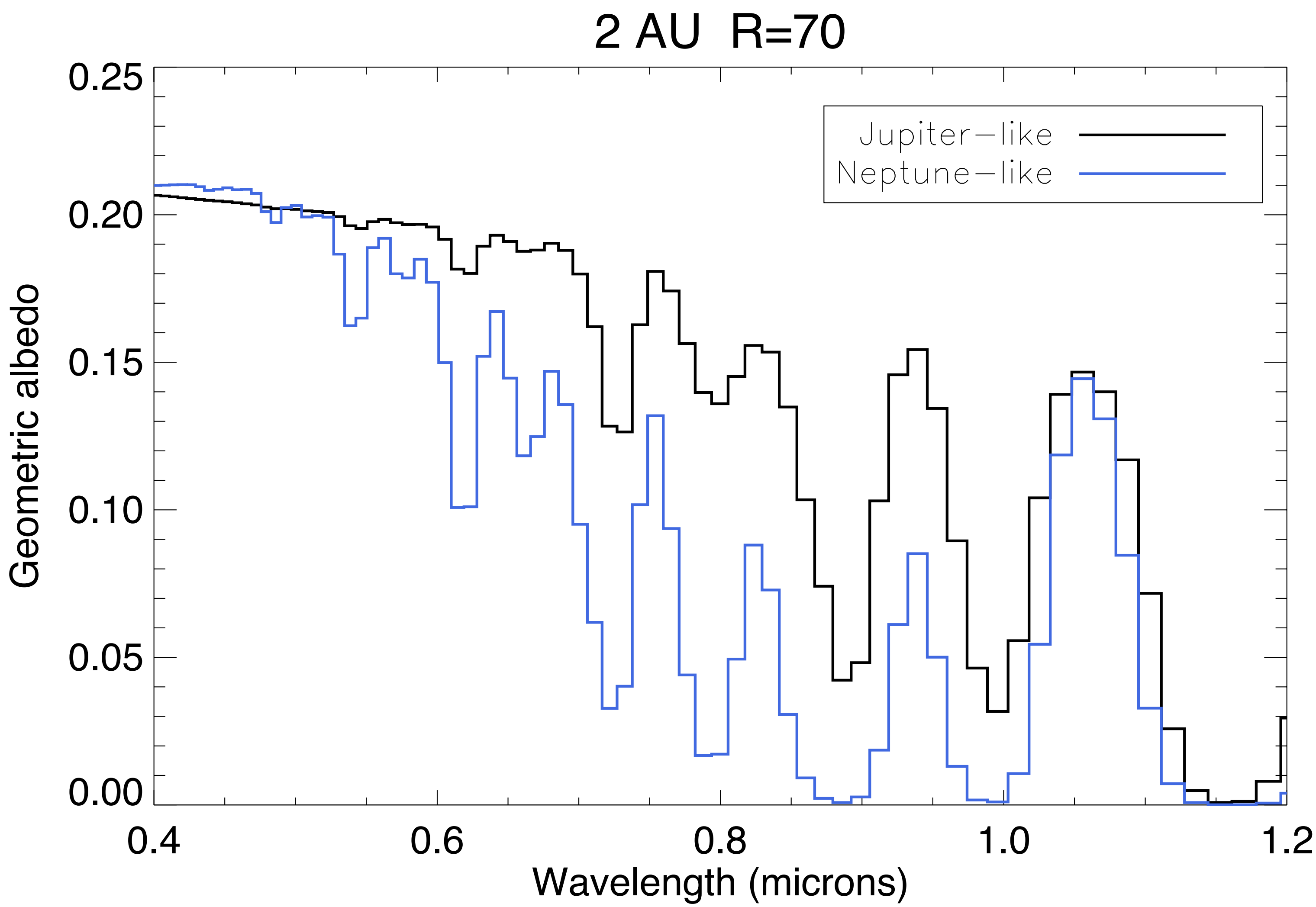
1) Survey 200 nearby stars including both those with known extrasolar planets and those for which no constraints will exist (e.g. A stars) spanning the range of spectral types
2) Characterize a significant sample (10-20) of giant planets in broadband reflected-light photometry with an accuracy of 0.03 in albedo, spanning a ~5 bands that are sensitive from Rayleigh scattering to methane absorption
3) Spectroscopically characterize a subset (6-10) of giant planets spanning a range of irradiances and determine the depth of methane, water, and other features
   - Detect a sample (~2-4) of planets of less than 3 RE in broadband photometry of at least 3 bands with an accuracy of 0.05 in albedo
4) Characterize the orbital semi-major-axis (within 20%) and eccentricity (within 0.2) of these planets, in conjunction with Doppler or astrometric measurements

Planets within 30 pc



Macintosh & Savransky
Kepler-consistent RF; 1.9 pl/star
Main sequence non binary stars

R~70 spectra can determine planet properties



AFTA WFIRST
Wide-Field Infrared Survey Telescope

Disk Science

7) Search for low surface density circumstellar disks around a sample of several dozen nearby stars.

8) Measure the location, surface density and extents of dust particles around nearby stars from habitable zones to beyond ice lines to understand delivery of materials to inner solar systems

9) Constrain dust grain compositions and sizes

10) Detect and measure substructures within dusty debris that can be used to understand the locations of parent bodies (asteroids, comets) and influences of seen and unseen planets

11) Identify what nearby stars have zodiacal dust levels indicating they may be poor candidates for future terrestrial planet imaging

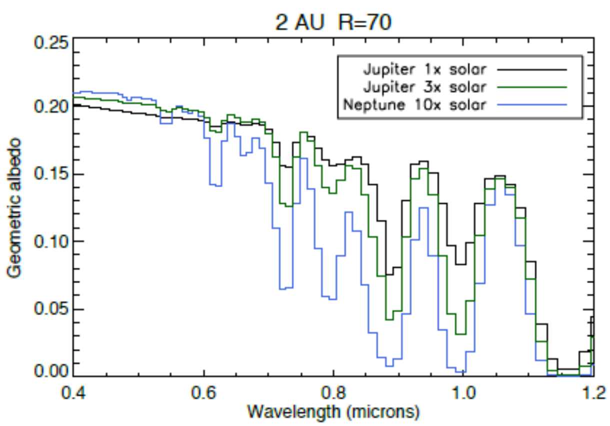
12) Understand the time evolution of circumstellar disk properties around a broad star sample

AFTA Coronagraph Instrument

Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument

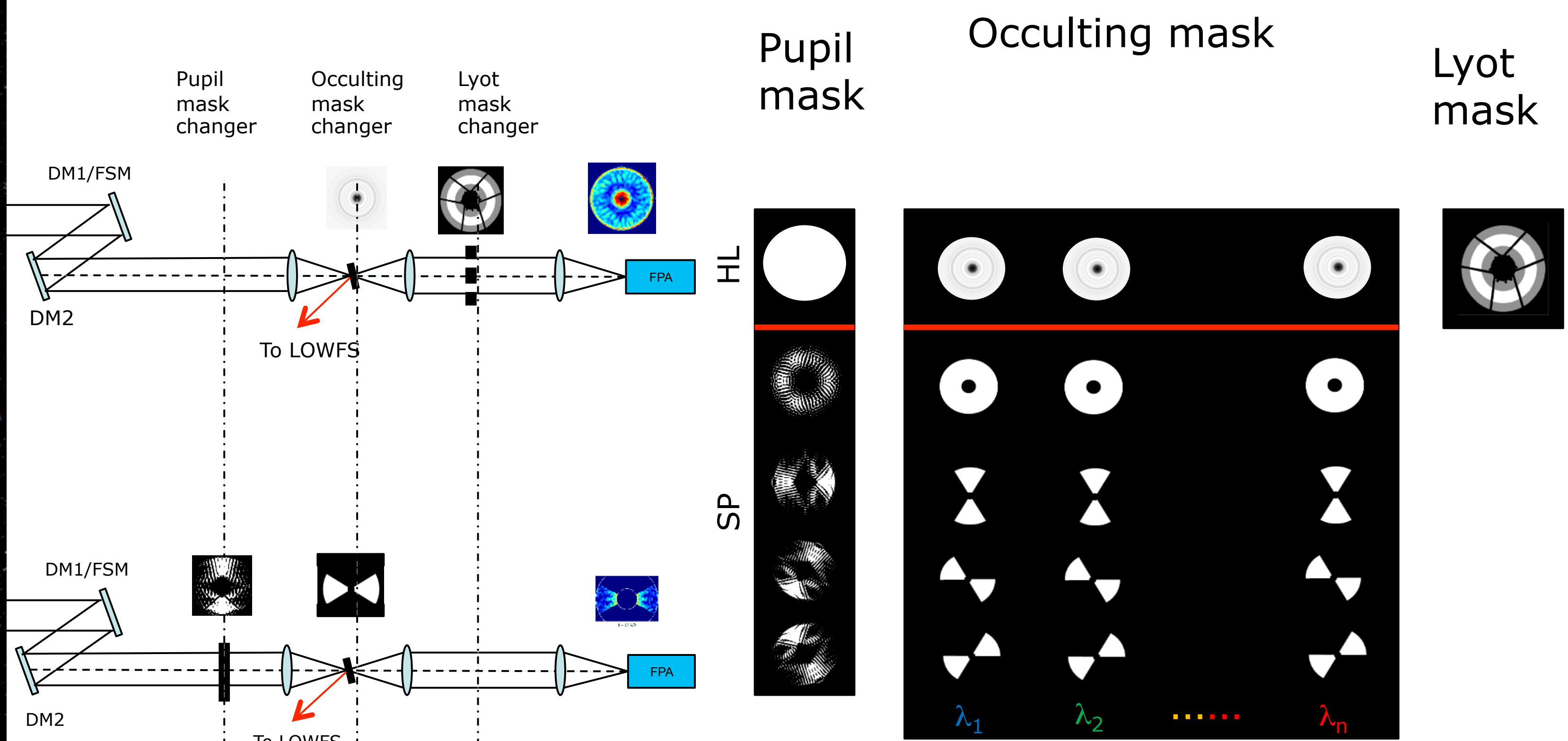


Exo-planet Spectroscopy

Bandpass	430 – 980nm	Measured sequentially in five ~10% bands
Inner working angle	100 – 250 mas	~3λ/D, driven by science
Outer working angle	0.75 – 1.8 arcsec	By 48X48 DM
Detection Limit	Contrast ≤ 10^{-9} After post processing)	Cold Jupiters, Neptunes, down to ~2 RE
Spectral Res.	~70	With IFS, R~70 across 600 – 980 nm
IFS Spatial Sampling	17mas	Nyqust for λ~430nm

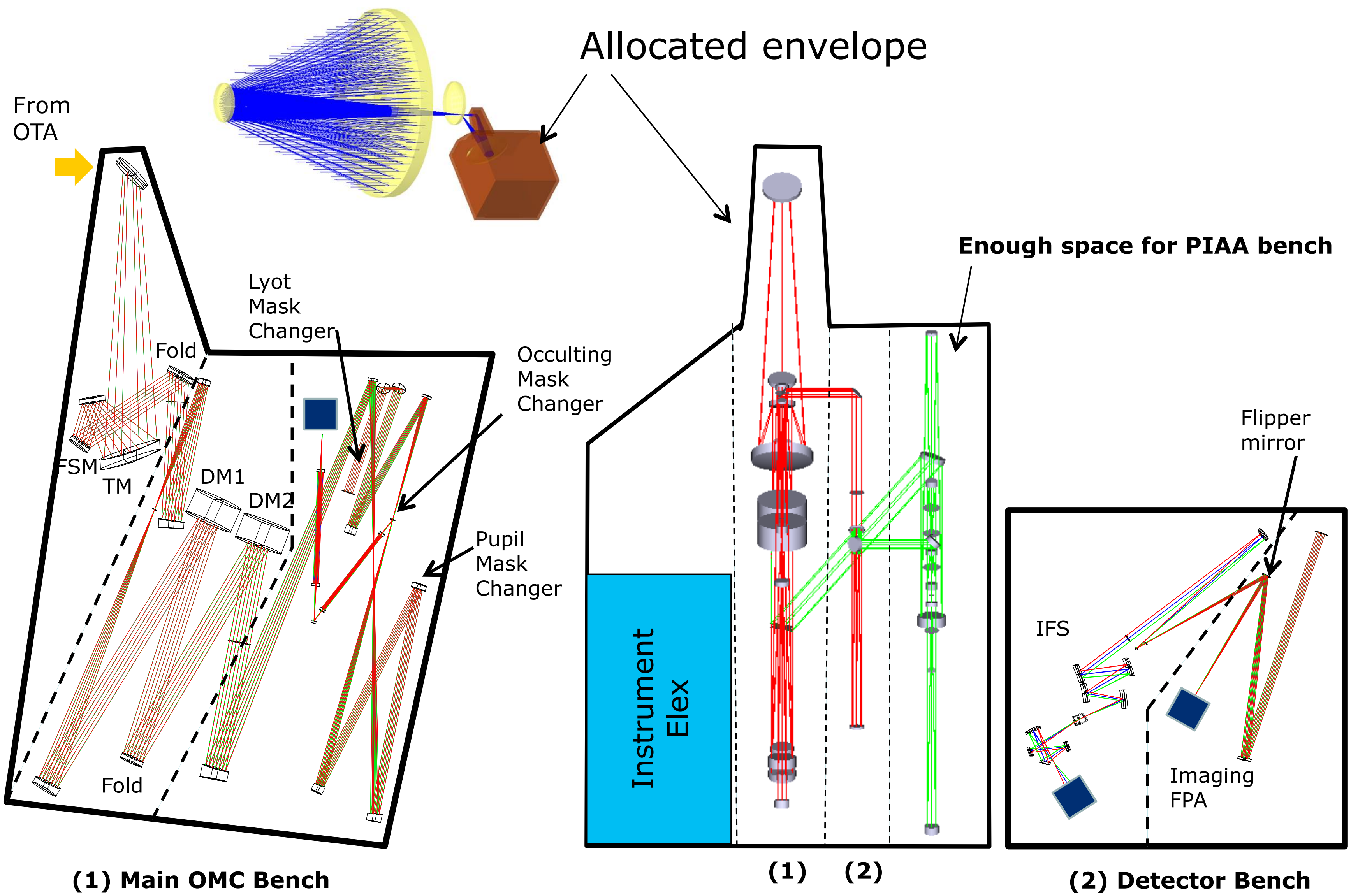
Primary Architecture:
Occulting Mask Coronagraph = Shaped Pupil + Hybrid Lyot

– SP and HL masks share very similar optical layouts
– Small increase in over all complexity compared with single mask implementation



A backup architecture using a higher performing Phase Induced Amplitude Apodization (PIAA) coronagraph is also being studied.

Instrument Layout within the Allocated Envelope

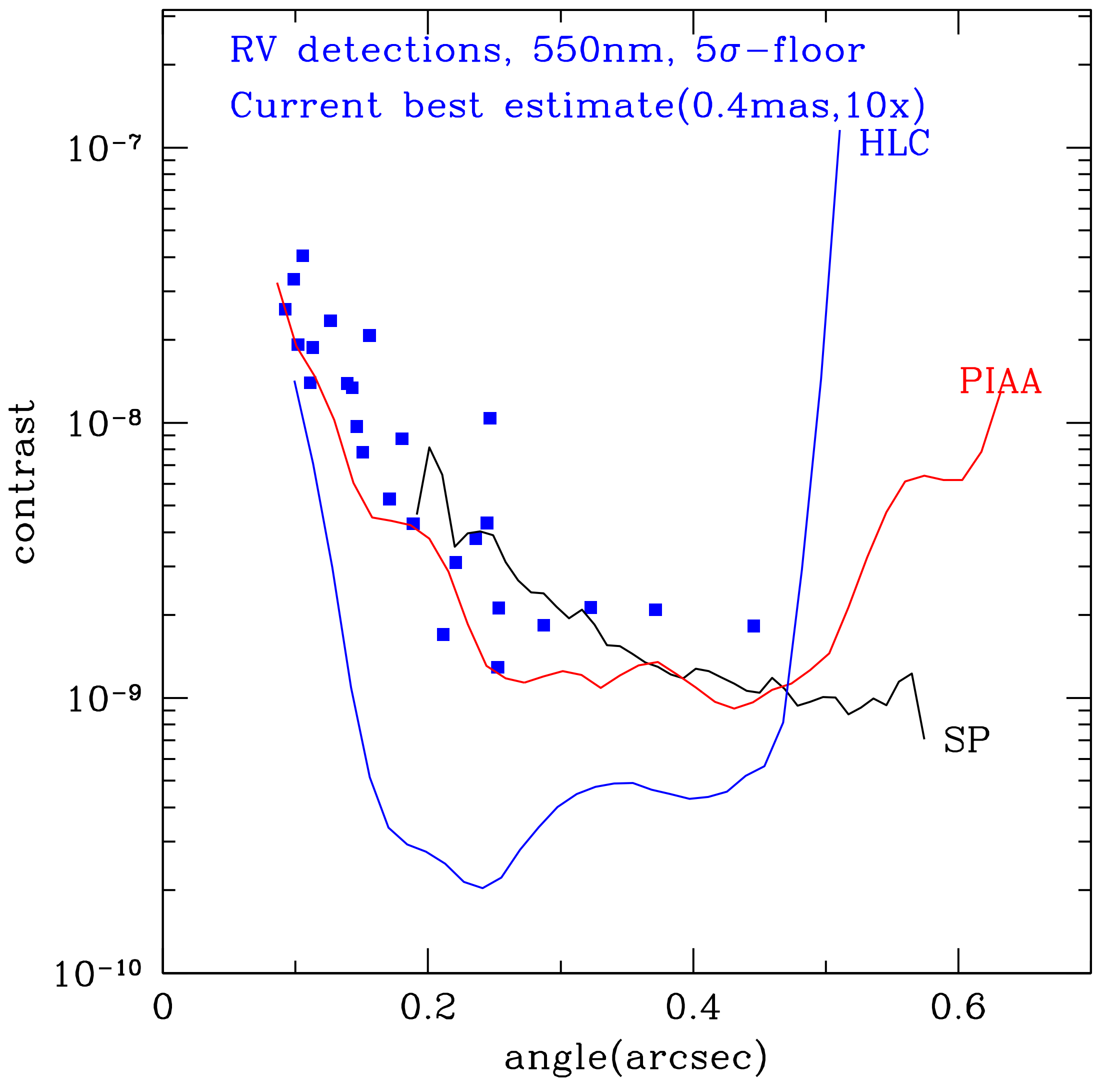


Science modeling (Wes Traub)

- Science yield modeling focusing on ability to study Doppler planets
- Contrast curves generated from John Krist PROPER models
  - Very dependent on telescope jitter assumptions
  - Recent SPOT modeling shows jitter < 0.4 marcsec rms
- Model residual speckle noise, photon noise from halo, photon noise from foreground and background zodiacal light, detector noise sources
- Significant uncertainty in removal of speckles through post-processing and PSF subtraction

Contrast vs Angle from Star

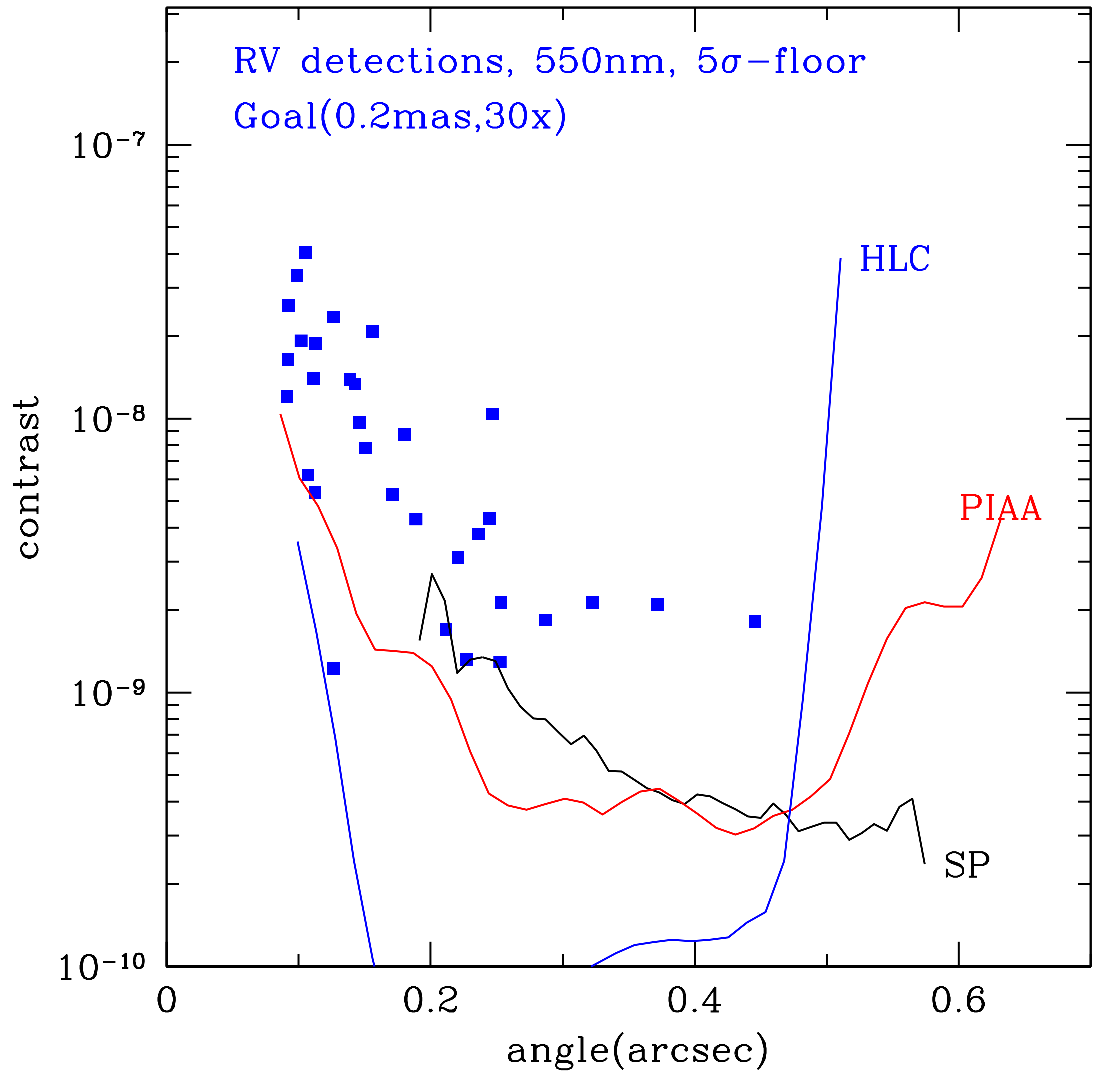
Current best estimate jitter & post-processing factor



Contrast floors here are upper limit for long exposure/very bright star

Contrast vs Angle from Star

Goal jitter & post-processing factor



Contrast floors here are upper limit for long exposure/very bright star

AFTA RV Exoplanet Detection Estimates

- RV exoplanet detections are estimated based on imaging of radial velocity planets from the current RV catalog

Configuration	Design	Inner working angle	# RV planets, 550nm band, 6-month campaign	# spectral bands per target, 6-month campaign
Prime (OMC: Occulting Mask Coron.)	**SP**	0.19	4 7	4.3 4.9
	HL	0.10	18 19	4.3 4.2
Backup	**PIAA**	0.09	23 30	3.2 4.3

Note 1. Two rows for contrast and # RV images columns are for cases of

- Current Best Estimate: 0.4 mas RMS jitter & 1 mas star, 10x post-processing factor (slide 4)
- Goal: 0.2 mas RMS jitter & 1 mas star, 30x post-processing factor (slide 5)

Note 2. Spectral bands are 10% wide, centered at 450, 550, 650, 800, 950 nm

Future science tasks

- Evaluate spectroscopic capabilities of new designs
  - Requires coronagraph modeling at 800 nm
- Evaluate capabilities for 1-4 RE planets
- Assess Doppler completeness of likely target sample
- Additional integrated modeling of coronagraph
- Assess likely disk imaging science using refined coronagraphic capabilities and integrated simulations
- Evaluate speckle removal requirements and capabilities
- Develop mission scenarios

Coronagraph technology development

- Finalize designs for testing
- Manufacture masks and stops Winter/Spring 2014
- Begin HCIT vacuum facility testing Spring/Summer 2014
- Perform static wavefront control tests followed by dynamic tests with jitter through Summer 2016.
- Goal of TRL 5 by October, 2016.

Conclusions

AFTA-WFIRST with a coronagraph will be the first high-contrast, small inner working angle instrument in space with wavefront correction capability. It is an important first step to a future large mission capable of detecting and characterizing Earth-size rocky planets in the habitable zone of nearby stars.

Acknowledgements

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